Spin tune reduction by matching DX prime at snakes for Run-17

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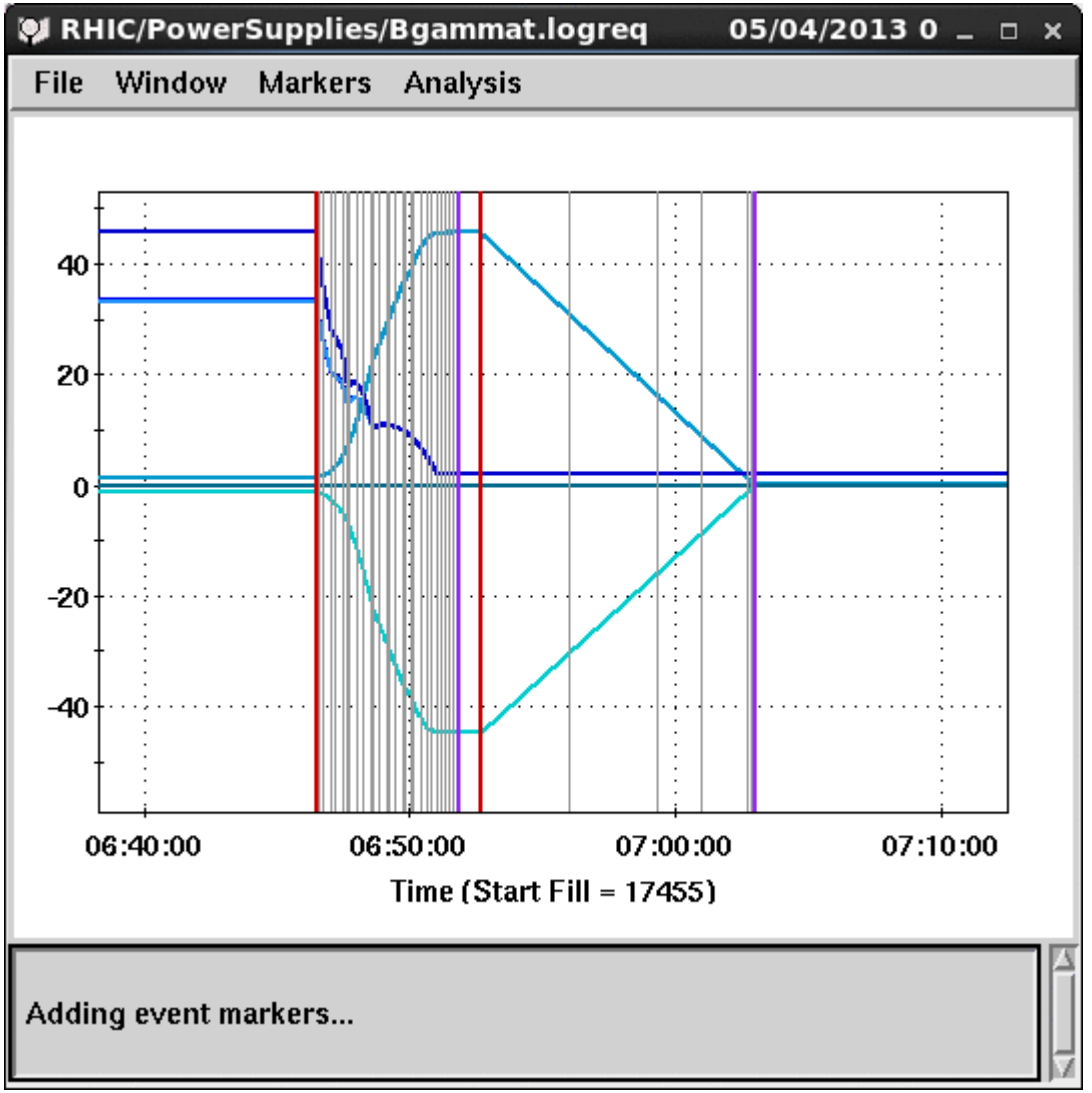
Motivation

- The spin tune spread is proportional to the difference of DX primes at the two snakes.
- There is a plan for further study on the spin tune meter during Run-17.
- The reduction of spin tune helps preserve polarization better when the beam cross resonances on the ramp.

History of DX prime matching

- I worked with D. Trbojevic and E. Courant in 2012 on some theoretical study of matching DX primes at the snakes using qf8 and qf9 quadrupoles. It was not implemented due to limited current range of power supplies.
- J. Kewisch came up with a solution by using gamma-t quadrupoles with some being flipped polarity. It was implemented operationally in blue ring for about a month in Run-13. It was not clear the end result was positive or negative.

Gamma-t current in 2013



The implementation is from fill number ~17430-17530.

Polarization

Principles

Dispersion change: $$\Delta D_i = D_i^* - D_i = -G_x(s_i, s_j) K_j D_j$$

$$G(s, s_0) = \frac{\sqrt{\beta(s)\beta(s_0)}}{2 \sin \pi\nu} \cos(\pi\nu - |\psi(s) - \psi(s_0)|)$$

Beta beat: $$\frac{\Delta\beta(s)}{\beta(s)} = -\frac{1}{2 \sin \Phi_0} \int_s^{s+C} k(s_1)\beta(s_1) \cos[2\nu_0(\pi + \phi - \phi_1)]\, ds_1$$

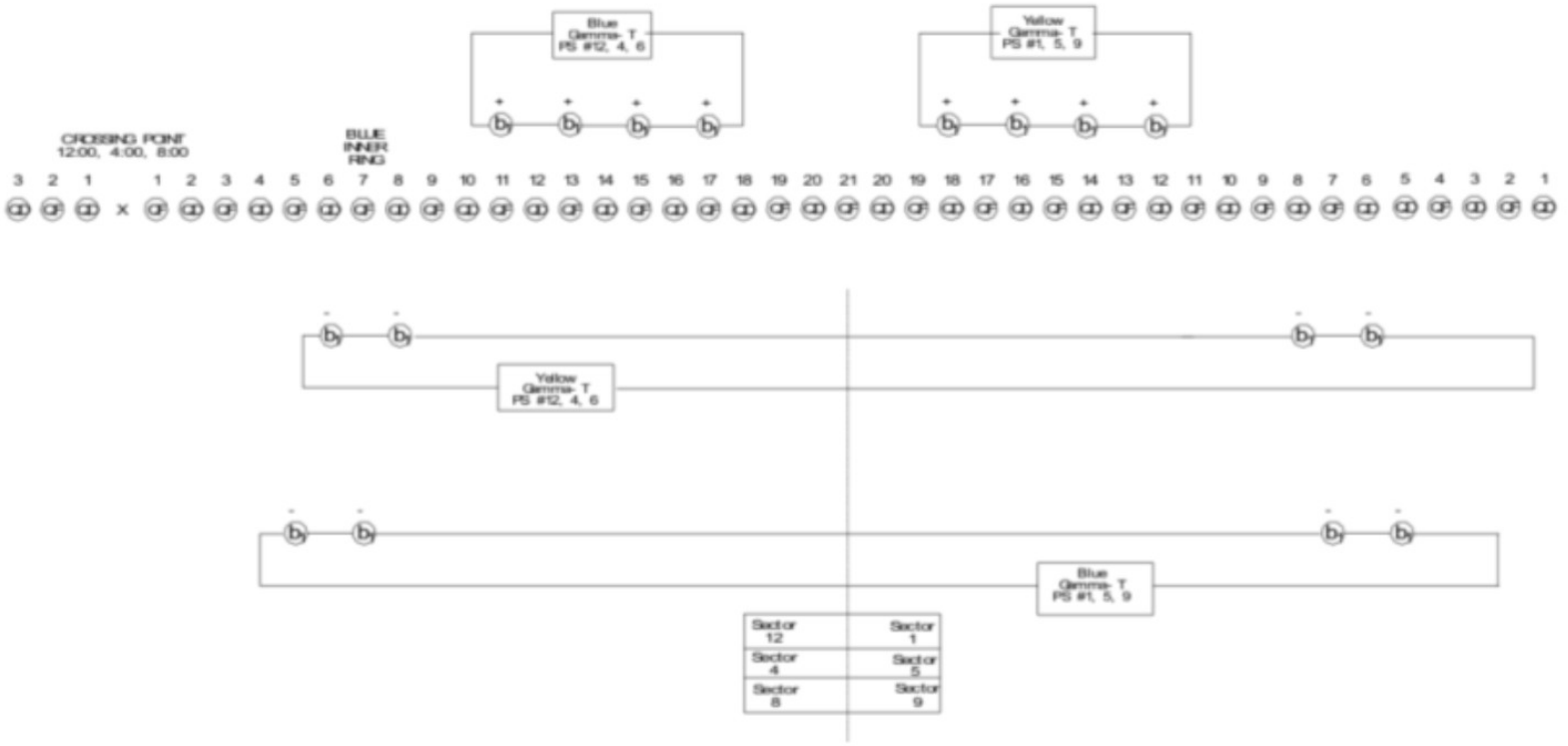
Tune change: $$\Delta\nu = \frac{1}{4\pi} \oint \beta(s_1) k(s_1) ds_1$$

[1] S. Y. Lee, Accelerator physics. World Scientific Publishing Company Incorporated, 2004.

Wiring scheme

- There are four arc gamma-t quads in each family (6 families per ring). The last two quads were flipped so that dispersion distortion from quads add up and beta beat cancel (more or less).
- For normal operation, only the non-arc ones were used for gamma-t tuning. The polarity of the arc ones were flipped for D prime matching. In case one has to revert back to Run-13 lattice, it doesn't interfere with normal operation to flip the arc ones during shutdown.

Gamma-t quads



See the wiring scheme for gamma-t quadrupoles on page 177 and 178 in the design manual:
https://www.bnl.gov/cad/accelerator/docs/pdf/RHICConfManual.pdf

Solution @store in blue

- The current range of the gamma-t quadrupoles are +/-50 A (Don).
- The non-arc ones were employed in the matching for Run17 lattice so that the current limits were met.
- The DX primes are -0.0221 and -0.0218 at sector-3 and 9 snakes.
- With the same wiring scheme, a solution can be found at injection as well.

Strength and wiring

- k1l_bo6_qgt12 = 0.00160611687 ; +
- k1l_bo6_qgt14 = 0.00160611687 ; +
- k1l_bo6_qgt16 = -0.00160611687 ; -
- k1l_bo6_qgt18 = -0.00160611687 ; -
-
- k1l_bi8_qgt11 = -0.001778884689 ; +
- k1l_bi8_qgt13 = -0.001778884689 ; +
- k1l_bi8_qgt15 = 0.001778884689 ; -
- k1l_bi8_qgt17 = 0.001778884689 ; -
-
- k1l_bo10_qgt12 = 0.0001713904604 ; +
- k1l_bo10_qgt14 = 0.0001713904604 ; +
- k1l_bo10_qgt16 = 0.0001713904604 ; +
- k1l_bo10_qgt18 = 0.0001713904604 ; +
-
- k1l_bi12_qgt11 = -9.809838796e-05 ; +
- k1l_bi12_qgt13 = -9.809838796e-05 ; +
- k1l_bi12_qgt15 = 9.809838796e-05 ; -
- k1l_bi12_qgt17 = 9.809838796e-05 ; -
-
- k1l_bo2_qgt12 = -9.236446672e-05 ; +
- k1l_bo2_qgt14 = -9.236446672e-05 ; +
- k1l_bo2_qgt16 = 9.236446672e-05 ; -
- k1l_bo2_qgt18 = 9.236446672e-05 ; -
-
- k1l_bi4_qgt11 = 0.001787685581 ; +
- k1l_bi4_qgt13 = 0.001787685581 ; +
- k1l_bi4_qgt15 = -0.001787685581 ; -
- k1l_bi4_qgt17 = -0.001787685581 ; -

k1l_bo6_qgt6 = -0.0002955713138 ;
k1l_bo6_qgt8 = -0.0002955713138 ;
k1l_bo7_qgt8 = -0.0002955713138 ;
k1l_bo7_qgt6 = -0.0002955713138 ;

k1l_bi8_qgt5 = 0.0002100633279 ;
k1l_bi8_qgt7 = 0.0002100633279 ;
k1l_bi9_qgt7 = 0.0002100633279 ;
k1l_bi9_qgt5 = 0.0002100633279 ;

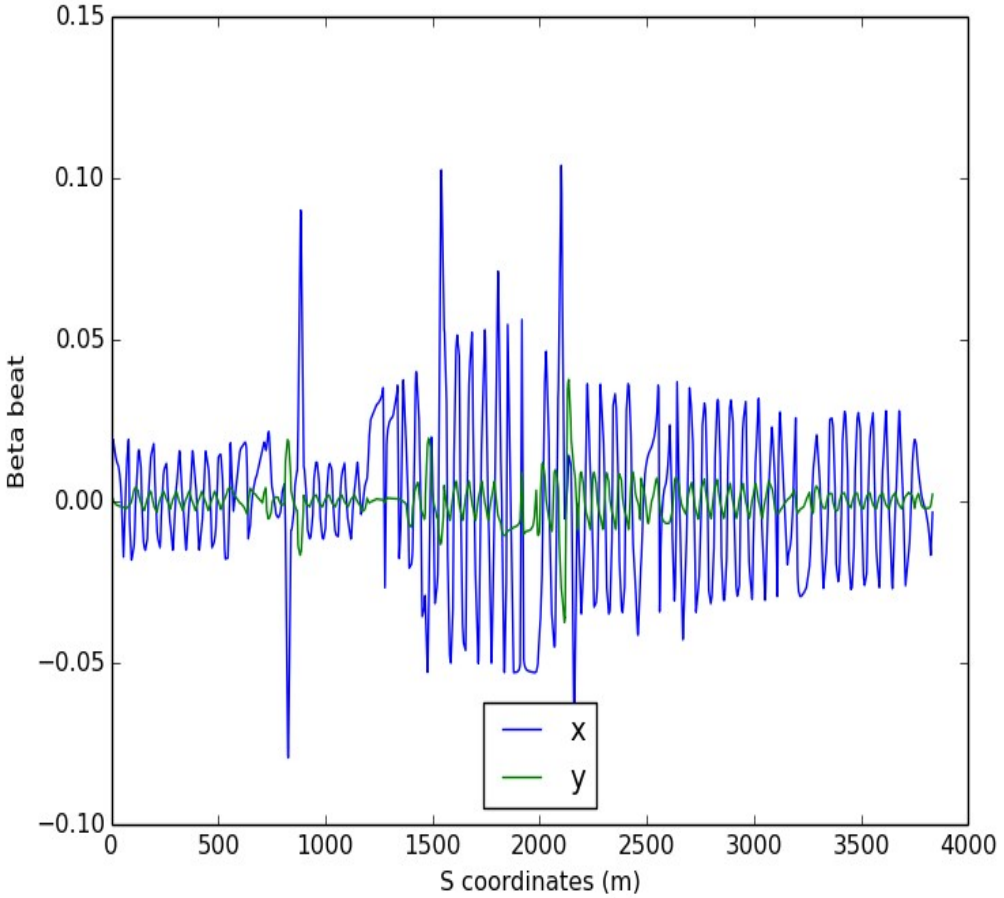
k1l_bo10_qgt6 = 0.0002626918032 ;
k1l_bo10_qgt8 = 0.0002626918032 ;
k1l_bo11_qgt8 = 0.0002626918032 ;
k1l_bo11_qgt6 = 0.0002626918032 ;

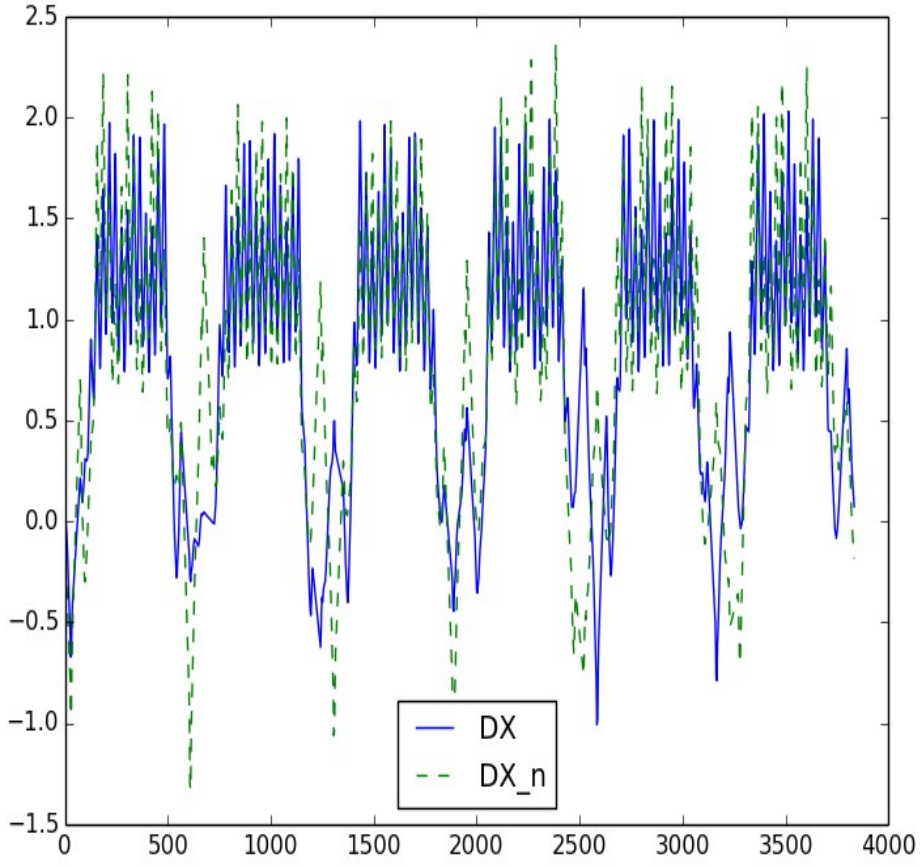
k1l_bi12_qgt5 = 0.0002448414599 ;
k1l_bi12_qgt7 = 0.0002448414599 ;
k1l_bi1_qgt7 = 0.0002448414599 ;
k1l_bi1_qgt5 = 0.0002448414599 ;

k1l_bo2_qgt6 = 0.000209503374 ;
k1l_bo2_qgt8 = 0.000209503374 ;
k1l_bo3_qgt8 = 0.000209503374 ;
k1l_bo3_qgt6 = 0.000209503374 ;

k1l_bi4_qgt5 = -0.0002931198468 ;
k1l_bi4_qgt7 = -0.0002931198468 ;
k1l_bi5_qgt7 = -0.0002931198468 ;
k1l_bi5_qgt5 = -0.0002931198468 ;

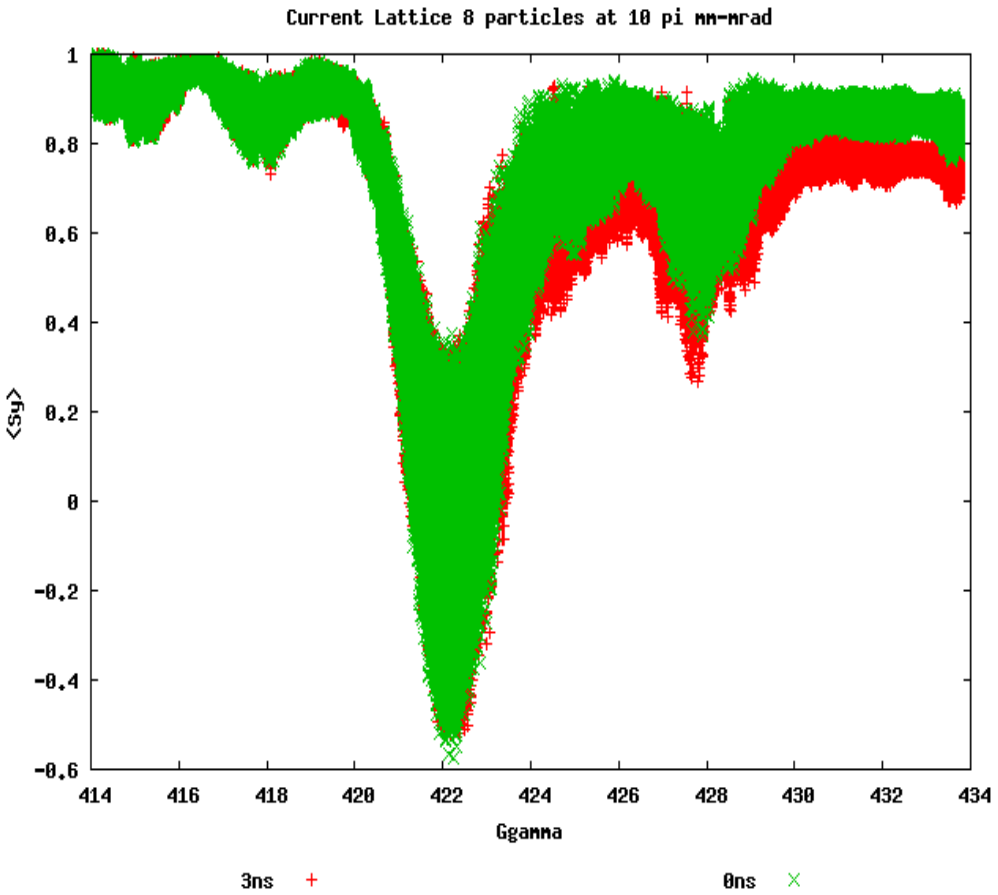
Beta and dispersion



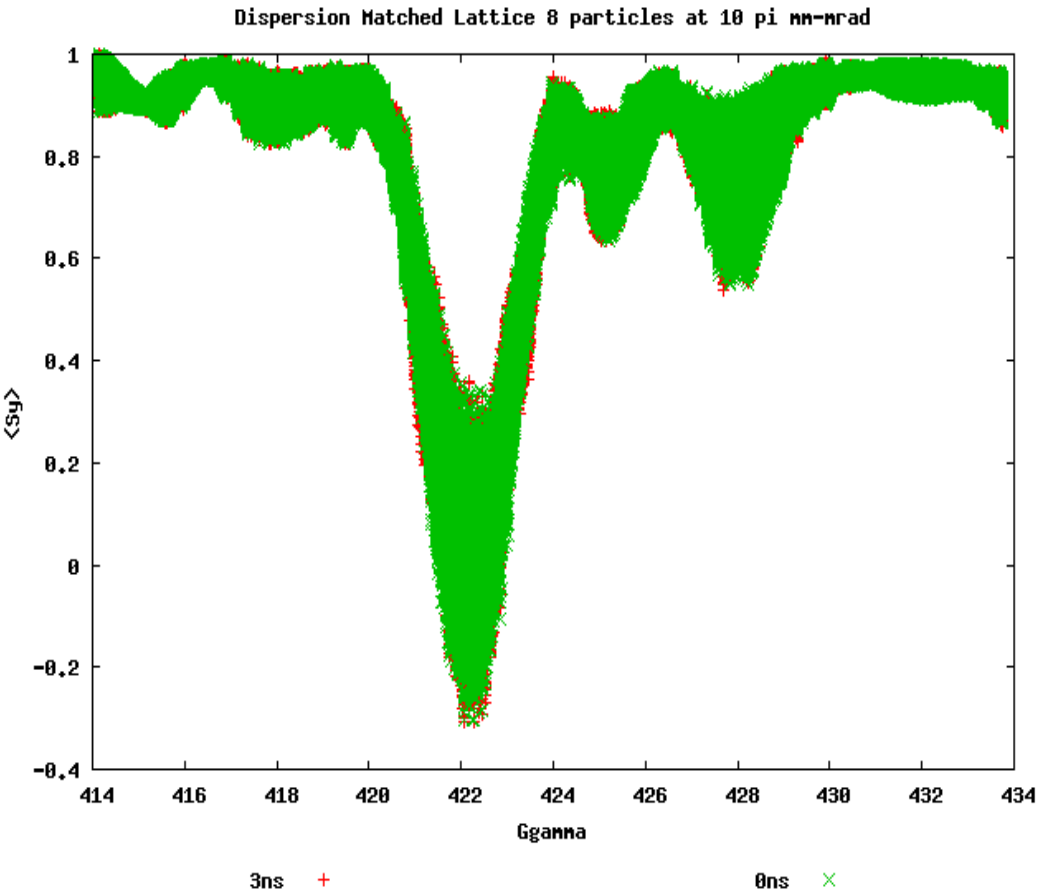


Spin tracking results

Before DX prime matched:



After DX prime matched using qf8&qf9 solution:



Courtesy by Vahid

Plans

1. At injection, take dispersion measurement. Implement gamma-t changes, take dispersion measurement again to confirm the calculated D prime change. The required time is 1 hrs at injection.

2. At store, confirm experimentally the calculated DX prime change.

3. Take spin tune measurement at store, one should be able to observe that the spin oscillation amplitude is enhanced with driving tune closer to the spin tune.

4. If everything indicates positive impact of the D prime matching, the next step is to implement on the ramp.

Summary

1. The D prime matching solutions in both rings for the new lattice were found.
2. The required polarity flip is scheduled to be done before run starts.
3. The impact of the D prime matching on dynamics aperture and spin are being evaluated.
4. The main purpose is to enhance the signal level of spin tune measurement.
5. The requested APEX time for the D prime matching development is about 4 hrs.